STRATFORD/AVON RIVER ENVIRONMENTAL MANAGEMENT PROJECT

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DISPERSION OF THE STRATFORD SEWAGE TREATMENT PLANT EFFLUENT INTO THE AVON RIVER

Technical Report S-8

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PREFACE

This report is one of a series of technical reports resulting from work undertaken as part of the Stratford-Avon River Environmental Management Project (S.A.R.E.M.P.).

This two year project was initiated in April 1980, at the request of the City of Stratford. The S.A.R.E.M.P. is funded entirely by the Ontario Ministry of the Environment. The purpose of the project is to provide a comprehensive water quality management strategy for the Avon River basin. In order to accomplish this considerable investigation, monitoring and analysis has taken place. The outcome of these investigations and field demonstrations will be a documented strategy outlining the program and implementation mechanisms most effective in resolving the water quality problems now facing residents of the basin. The project is assessing urban, rural and in-stream management mechanisms for improving water quality.

This report results directly from the aforementioned investigations. It is meant to be technical in nature and not a statement of policy or program direction. Observations and conclusions are those of the author and do not necessarily reflect the attitudes or philosophy of all agencies and individuals affiliated with the project. In certain cases, the results presented are interim in nature and should not be taken as definitive until such time as additional support data are collected.

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ABSTRACT

As part of the Stratford-Avon River Environmental Management Project, the Water Resources Branch of the Ontario Ministry of the Environment investigated the possibility of creating a shore-attached effluent plume and mixing zone boundaries in the Avon River below the Stratford Water Pollution Control Plant (WPCP). In a survey conducted on June 18, 1980, Rhodamine-WT dye analyzed with standard fluorometric techniques was used as a tracer to determine the extent of the WPCP mixing zone. Data from the survey were used to calibrate the mixing zone model MIXAPPLN; MIXAPPLN was then used to make predictions of allowable total residual chlorine (TRC) and ammonia concentrations in WPCP effluent under various effluent and streamflow conditions.

Survey results indicate that at 247 m downstream of the WPCP outfall, the effluent has completely crossed the stream (however, concentrations at that point are not uniform across the stream). These observations suggest that it may be necessary to realign the outfall position and perhaps channelize the river bed downstream of the outfall in order to create a shore-attached effluent plume and a zone of passage for aquatic fauna.

Results of subsequent computer modelling indicate that allowable effluent concentrations depend on the size of the limited use zone. For example, a limited use zone of 40% of the river width can be achieved with TRC concentrations in the effluent of 80 ug/L under the most favourable conditions, and 13 ug/L under the worst, to meet Provincial Water Quality Objectives (PWQO). By contrast, to achieve a 20% limited use zone, effluent requirements are much more stringent. Under the most favourable conditions, only 6 ug/L TRC is allowable in the effluent, and this falls to 4 ug/L under the worst conditions.

For ammonia, similar patterns are observed. To achieve a 40% limited use zone under the most favourable conditions, the maximum allowable total ammonia concentration in the effluent is 4 mg/L. Under more typical summer conditions of average flow, high temperature and high pH, effluent concentrations would have to be restricted to less than 1.0 mg/L. For a 20% limited use zone, the effluent requirements for total ammonia are still more stringent, as they were for TRC. Under the most favourable conditions, the maximum allowable total ammonia concentration in the effluent is 2 mg/L. Under more typical summer conditions, the allowable effluent concentration falls to 0.39 mg/L.

Because these levels are lower than are usually observed in the WPCP effluent, modifications to the WPCP processes or structure (e.g. dechlorination, improved nitrification) should be evaluated in order to assess the feasibility and cost of meeting the provincial water quality objectives for chlorine and ammonia under summer conditions.

ACKNOWLEDGEMENTS

The author would like to thank Mr. M. Fortin for the technical guidance provided in the preparation of this report and Dr. I. Heathcote and Messrs. C. Schenk and D. Veal for reviewing it. Word processing by Mrs. C. Parkes and Ms. V. Sokolyk is gratefully acknowledged.

INTRODUCTION

Total residual chlorine (TRC) and ammonia are present in wastewater effluents and can be toxic to aquatic biota in streams or rivers where the effluents are discharged. The toxic effects of these pollutants can be reduced by suitable placement of the outfalls in receiving rivers or streams, or effluent concentrations can be reduced to achieve desirable instream levels. In some cases, both outfall redesign and effluent concentration reduction are required if TRC and ammonia are to meet the Provincial Water Quality objectives. This report examines TRC and ammonia mixing phenomena downstream of the Stratford Water Pollution Control Plant (WPCP) and estimates desirable levels of TRC and ammonia in the WPCP effluent that would satisfy water quality objectives.

The June 1979 report, "Impact of Waste Inputs on the Quality of the Avon River", published by the Water Resources Assessment Unit, Technical Support Section, Ministry of the Environment, Southwestern Region, indicated that TRC levels lethal to fish life and exceeding the MOE objective of 2 ug/L are observed for at least 500 feet downstream of the Stratford WPCP during low-flow periods. The report also indicated that the WPCP contributes 72 percent of the annual ammonia load to the Avon River which, combined with industrial discharges (22 percent), has caused ammonia levels to exceed the MOE objective of 0.02 mg/L. Aside from one other pollutant (chromium), TRC and ammonia are the principal toxicants with the potential to directly affect fish life downstream of the WPCP.

In an effort to provide more detailed information about physical processes in the Avon River affecting effluent mixing, an experiment to measure lateral diffusion was carried out by MOE Water Resources Branch staff on June 18, 1980. The measurement of lateral diffusion was made by tracing the mixing pattern of Rhodamine-Wt dye below the WPCP outfall. The main rationale of the experiment was to investigate the possibility of creating a shore-attached effluent plume (thereby allowing a zone of passage for fish) and to determine chlorine and ammonia mixing zone boundaries below the WPCP outfall. Results from the experiment were used to calibrate the mixing zone model MIXAPPLN, which was then used to predict allowable TRC and ammonia levels in WPCP effluent under various design conditions, given that MOE objectives for those parameters should be met in the stream itself. Complete details and documentation of the mixing zone model, MIXAPPLN are presented in Ontario Ministry of the Environment Water Resources Paper 14.

This report presents the findings of field and modelling investigations of Stratford WPCP effluent mixing phenomena and allowable effluent concentrations for TRC and total ammonia.

DESCRIPTION OF THE STUDY AREA

The analysis presented in this report is restricted to the area of the Stratford WPCP mixing zone. Figure 1 is a map showing the location of the WPCP outfall, the dye injection point and the four transects used in the investigation.

The dye injection point was located 0.3 m from the left bank on Transect A and 56 m downstream of the outfall; the river is 13 m wide at this point. Transect B was 11.5 m wide and 122 m downstream of the outfall, Transect C was 7.0 m wide and 171 m downstream of the outfall, and Transect D was 10.0 m wide and 247 m downstream of the outfall. Streamflow at the first transect on the survey date was 0.4 m^3/sec.

METHODS

A mariotte (constant head) tank was used to inject a Rhodamine-WT dye solution of 1.6 x 10^6ug/L concentration at 0.3 m from the left bank and at a constant rate for approximately 1.5 hours. At the end of that time and after the visible dye pattern had stabilized, water samples and velocity measurements were taken at 0.5 m intervals across Transects B, C, and D (Figure 1). Water samples were then brought back to Toronto for fluorescence analysis. A Turner Designs Model 10 fluorometer and standard fluorometric procedures were used for all sample analyses. Data from the dye study were used to calibrate the mixing zone model MIXAPPLN, which was then applied to determine mixing zone boundaries and allowable effluent concentrations for the WPCP.

Decay rates of total residual chlorine (TRC) are highly variable in natural rivers, ranging between 5.6 x 10^{-5}/sec and 73 x 10^{-4}/sec at 20^{o}C (base e) (T. P. H. Gowda, M.O.E., 1981; personal communication). Since TRC decay rates for the Avon River were not readily available, predictions using MIXAPPLN were made with the highest decay rate in the observed range. This value seemed to be more appropriate than the lower one due to the shallow turbulent nature of the stream. The instream decay rate of total ammonia was taken as 2.31 x 10^{-5}/sec (to base e) (T.P.H. Gowda, MOE, 1981; personal communication). This value was also based on studies carried out in the Grand River below the Waterloo WPCP.

Tables 1 and 2 sum up the case study modelling inputs giving the range of values considered for temperature effluent concentration, effluent flow, streamflow and pH for dry and wet weather conditions for TRC and total ammonia, respectively.

Modelling inputs were estimated from observed data. The 3-year operation record (1979-1982) for Stratford WPCP was used to calculate the average and maximum effluent concentration of NH_3 for three seasons: spring (April-May), summer (June-October), and fall (October -November). An effluent TRC concentration of 0.5 mg/L was assumed for dry weather (G. Zukovs, Pollution Control Branch, MOE, 1982; personal communication).

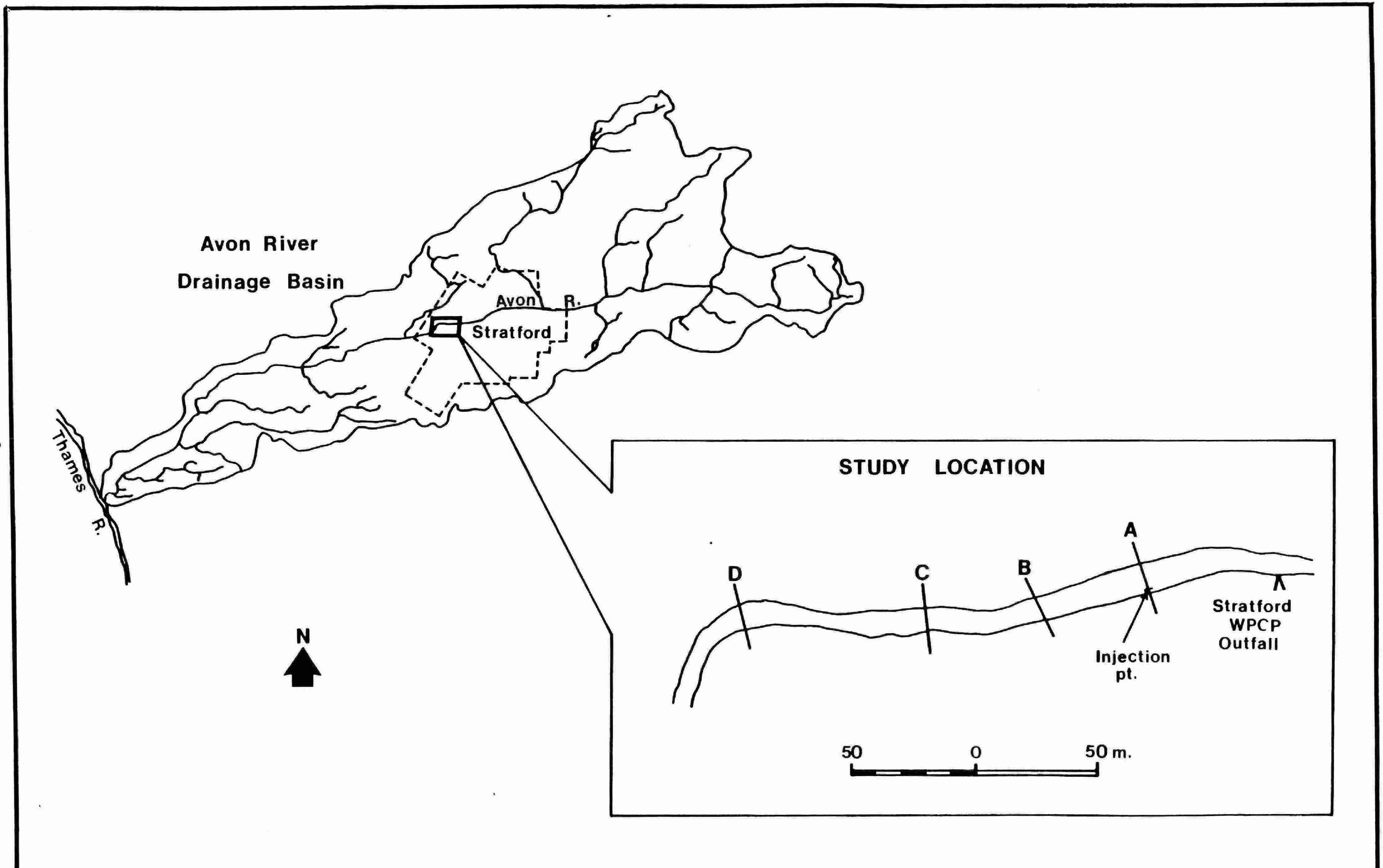


Figure 1: LOCATION OF STRATFORD WPCP OUTFALL, INJECTION POINT, AND THE FOUR TRANSECTS.

TABLE 1: SUMMARY OF VALUES CONSIDERED FOR TEMPERATURE, EFFLUENT CONCENTRATION, EFFLUENT FLOW, STREAMFLOW AND PH FOR TRC

Type of Event	Temp. (^{o}C)	Effluent Conc. (mg/L)	Effluent Flow (m^3/sec)	Stream-flow (m^3/sec)	pH*	Remarks**
Dry Weather:						
	10-15	0.50	0.197	0.250	7.0	Spring & Fall
	20-25	0.50	0.197	0.250	7.0	Summer
Wet Weather:						
(May 18/80)	17	0.18	0.889	6.778	7.0	Base Case
	17	0.30	0.827	6.716	7.0	Storage/Treatment
(July 28/80)	21	0.11	1.472	4.069	7.0	Base Case
	21	0.38	1.319	3.911	7.0	Storage/Treatment
(Aug. 11/80)	22	0.08	1.973	4.988	7.0	Base Case
	22	0.42	1.940	4.955	7.0	Storage/Treatment
(Sept. 17/80)	15	0.32	0.531	2.610	7.0	Base Case
	15	0.00	0.324	2.421	7.0	Storage/Treatment
(Sept. 22/80)	17	0.06	2.748	7.260	7.0	Base Case
	17	0.43	2.396	6.908	7.0	Storage/Treatment

* Built-into the program. Not a sensitive parameter for TRC.

** Base Case - existing treatment facilities
Storage/Treatment - new treatment based on additional wet weather storage and new primary clarifiers

TABLE 2: SUMMARY OF VALUES CONSIDERED FOR TEMPERATURE, EFFLUENT CONCENTRATION, EFFLUENT FLOW, STREAMFLOW AND PH FOR TOTAL AMMONIA

Type of Event	Temp. (°C)	Effluent Conc. (mg/L)	Effluent Flow (m^3/sec)	Stream-flow (m^3/sec)	pH	Remarks
Dry Weather:						
	10-15	8.20	0.197	0.250	7.7,8.1,8.5	Spring
	10-15	14.40	0.197	0.250	7.7,8.1,8.5	Spring Max. Obs.
	20-25	2.60	0.197	0.250	7.7,8.1,8.5	Summer
	20-25	12.60	0.197	0.250	7.7,8.1,8.5	Summer Max. Obs.
	10-15	2.60	0.197	0.250	7.7,8.1,8.5	Fall
	10-15	12.60	0.197	0.250	7.7,8.1,8.5	Fall Max. Obs.
Wet Weather:						
(May 18/80)	17	8.80	0.889	6.778	8.0	Base Case
	17	8.60	0.827	6.716	8.0	Storage/Treatment
(July 28/80)	21	10.20	1.472	4.069	7.7	Base Case
	21	10.00	1.319	3.911	7.7	Storage/Treatment
(Aug. 8/80)	22	10.80	1.973	4.988	7.7	Base Case
	22	10.80	1.940	4.955	7.7	Storage/Treatment
(Sept. 17/80)	15	6.18	0.531	2.610	7.9	Base Case
	15	2.50	0.324	2.421	8.0	Storage/Treatment
(Sept. 22/80)	17	11.18	2.748	7.260	7.7	Base Case
	17	11.06	2.396	6.908	7.7	Storage/Treatment

The 7Q2 flow at Station 6 (0.05 m^3/sec) plus the mean 1980 WPCP flow (0.197 m^3/sec) was taken as the design dry weather flow (see Statistical Analysis of Flow Data, SAREMP, File Report by M. Fortin and M. Seto). The minimum and maximum pH 7.7 and 8.5, respectively were taken from 1980/81 bi-monthly stream monitoring data for Station 7 just below the WPCP outfall. The geometric mean pH was 8.1.

For the wet weather simulations, five storms were modelled. These storms were selected to characterize the thirteen WPCP bypass events modelled by W. Wong of the Pollution Control Branch, Wastewater Treatment Section. pH values were based on a flow-weighted geometric mean of effluent and stream values. Wet weather TRC effluent concentrations were estimated assuming a concentration of 0.5 mg/L for treated effluent and 0.0 mg/L for bypass flows. Temperatures were selected on the basis of continuous observed data collected by Southwestern Region at Stations 8 and 12.

RESULTS

Tables 3-5 show predictions of TRC mixing zone lengths and allowable TRC effluent concentrations for dry and wet weather conditions. Table 3 summarizes the dry weather analysis. Table 4 gives the summary of wet weather, base case modelling results, and Table 5, the wet weather analysis with additional storage and treatment for wet weather flows.

The corresponding modelling results for total ammonia are presented in Tables 6-11. For this analysis, the instream target concentration for unionized ammonia, the toxic fraction was 0.02 mg/L, the Provincial Water Quality Objective. Tables 6 and 8 are summaries of dry weather, spring, summer and fall results with the effluent concentration based on the Stratford WPCP 3-year average for each season. Tables 7 and 9 are similar summaries with the effluent concentrations based on the maximum observed concentrations. Wet weather results for base case and storage/treatment conditions are presented in Tables 10 and 11, respectively.

TABLE 3: SUMMARY OF RUNS FOR TRC MIXING ZONE ANALYSIS IN THE AVON RIVER
CONDITION: DRY WEATHER CONDITIONS*

QEFL (m^3/sec)	QPUP (m^3/sec)	TEMP (^oC)	PH	CEFL (ug/L)	XSCE (m)	CS = 2 ug/L QY/QT	CEA (ug/L)	XSCEA (m)
0.197	0.25	10.0	7.0	500	104.3	0.20	4.55	27.3
						0.30	13.57	43.9
						0.40	37.73	60.1
0.197	0.25	15.0	7.0	500	91.1	0.20	5.03	26.0
						0.30	16.01	40.9
						0.40	47.52	56.6
0.197	0.25	20.0	7.0	500	79.7	0.20	5.62	24.4
						0.30	19.19	38.3
						0.40	61.12	52.7
0.197	0.25	25.0	7.0	500	69.8	0.20	6.35	22.9
						0.30	23.37	36.2
						0.40	80.33	49.2

* GLOSSARY OF TERMS

QEFL	=	Effluent Flow
QPUP	=	Streamflow Immediately below the WPCP Outfall
CEFL	=	Effluent Concentration
XSCE	=	Longitudinal Mixing Zone Length
QY/QT	=	Lateral Boundary of Limited Use Zone, expressed as (partial cumulative discharge/total discharge)
CEA	=	Allowable Effluent Conc.
XSCEA	=	Longitudinal Boundary when Effluent conc. is CEA
CS	=	target instream concentration

TABLE 4: SUMMARY OF RUNS FOR TRC MIXING ZONE ANALYSIS IN THE AVON RIVER
CONDITION: WET WEATHER, BASE CASE CONDITIONS*

DATE	QEFL (m^3/sec)	QPUP (m^3/sec)	TEMP (^oC)	PH	CEFL (ug/L)	XSCE (m)	CS = 2 ug/L		
							QY/QT	CEA (ug/L)	XSCEA (m)
May 18/80	0.889	6.78	17.0	7.0	180	297.0	0.20	9.41	68.9
							0.30	18.32	116.2
							0.40	32.85	171.0
July 28/80	1.472	4.07	21.0	7.0	110	279.4	0.20	4.46	60.5
							0.30	9.25	99.5
							0.40	17.72	139.9
Aug. 11/80	1.973	4.99	22.0	7.0	80	294.3	0.20	4.06	64.1
							0.30	8.22	106.6
							0.40	15.39	150.4
Sept.17/80	0.531	2.61	15.0	7.0	320	263.1	0.20	7.36	52.1
							0.30	15.84	87.0
							0.40	31.53	121.0
Sept.22/80	2.748	7.26	17.0	7.0	60	323.0	0.20	3.84	74.5
							0.30	7.26	126.4
							0.40	12.65	194.1

* See Glossary of Terms, Table 3.

TABLE 5: SUMMARY OF RUNS FOR TRC MIXING ZONE ANALYSIS IN THE AVON RIVER
CONDITION: WET WEATHER, STORAGE/TREATMENT CONDITIONS*

DATE	QEFL (m^3/sec)	QPUP (m^3/sec)	TEMP (°C)	PH	CEFL (ug/L)	XSCE (m)	CS = 2 ug/L		
							QY/QT	CEA (ug/L)	XSCEA (m)
May 18/80	0.827	6.72	17.0	7.0	300	320.0	0.20	9.98	69.6
							0.30	19.45	115.6
							0.40	34.95	171.0
July 28/80	1.319	3.91	21.0	7.0	380	310.3	0.20	4.74	59.6
							0.30	9.92	97.5
							0.40	19.16	136.9
Aug. 11/80	1.940	4.95	22.0	7.0	420	369.2	0.20	4.09	64.2
							0.30	8.31	106.3
							0.40	15.56	149.9
Sept.22/80	2.396	6.91	17.0	7.0	430	517.5	0.20	4.13	73.2
							0.30	7.87	121.0
							0.40	13.82	193.0

N.B. On September 17, 1980, TRC concentration in the effluent was 0 ug/L.
* See Glossary of Terms, Table 3.

TABLE 6: SUMMARY OF RUNS FOR TOTAL AMMONIA MIXING ZONE ANALYSIS IN THE AVON RIVER
CONDITION: SPRING, DRY WEATHER, WPCP 3-YR. AVERAGE CONCENTRATION*

QEFL (m^3/sec)	QPUP (m^3/sec)	TEMP (^oC)	PH	CEFL (mg/L)	XSCE (m)	CS = 0.02 mg/L QY/QT	CEA (mg/L)	XSCEA (m)
0.197	0.25	10.0	7.7	8.2	1430.4	0.20	2.02	81.8
						0.30	3.05	202.7
						0.40	4.10	332.8
0.197	0.25	10.0	8.1	8.2	3472.6	0.20	0.82	83.1
						0.30	1.23	202.7
						0.40	1.66	332.8
0.197	0.25	10.0	8.5	8.2	5767.1	0.20	0.34	83.6
						0.30	0.51	202.7
						0.40	0.68	332.8
0.197	0.25	15.0	7.7	8.2	1540.6	0.20	1.39	81.0
						0.30	2.11	187.6
						0.40	2.87	313.0
0.197	0.25	15.0	8.1	8.2	2651.6	0.20	0.56	78.0
						0.30	0.86	187.6
						0.40	1.16	313.0
0.197	0.25	15.0	8.5	8.2	4017.6	0.20	0.24	78.2
						0.30	0.36	187.6
						0.40	0.49	313.0
0.197	0.25	20.0	7.7	8.2	1379.3	0.20	0.97	75.6
						0.30	1.49	180.4
						0.40	2.06	287.0
0.197	0.25	20.0	8.1	8.2	1949.2	0.20	0.40	75.8
						0.30	0.61	180.4
						0.40	0.84	287.0
0.197	0.25	20.0	8.5	8.2	2706.3	0.20	0.17	76.0
						0.30	0.26	180.4
						0.40	0.36	287.0

* See Glossary of Terms, Table 3.

TABLE 7: SUMMARY OF RUNS FOR TOTAL AMMONIA MIXING ZONE ANALYSIS IN THE AVON RIVER
CONDITION: SPRING, DRY WEATHER, MAXIMUM OBSERVED CONCENTRATION*

QEFL (m^3/sec)	QPUP (m^3/sec)	TEMP (^oC)	PH	CEFL (mg/L)	XSCE (m)	CS = 0.02 mg/L QY/QT	CEA (mg/L)	XSCEA (m)
0.197	0.25	10.0	7.7	14.4	2569.3	0.20	2.03	82.6
						0.30	3.07	202.9
						0.40	4.14	333.7
0.197	0.25	10.0	8.1	14.4	4784.9	0.20	0.82	83.4
						0.30	1.24	202.9
						0.40	1.67	333.7
0.197	0.25	10.0	8.5	14.4	7057.4	0.20	0.34	79.6
						0.30	0.51	203.0
						0.40	0.69	333.7
0.197	0.25	15.0	7.7	14.4	2127.2	0.20	1.40	81.6
						0.30	2.13	187.8
						0.40	2.89	313.9
0.197	0.25	15.0	8.1	14.4	3533.9	0.20	0.57	78.1
						0.30	0.86	187.8
						0.40	1.18	313.9
0.197	0.25	15.0	8.5	14.4	4809.4	0.20	0.24	78.2
						0.30	0.36	187.8
						0.40	0.49	313.9
0.197	0.25	20.0	7.7	14.4	1615.3	0.20	0.98	75.7
						0.30	1.50	180.6
						0.40	2.08	287.8
0.197	0.25	20.0	8.1	14.4	2468.6	0.20	0.40	75.9
						0.30	0.62	180.6
						0.40	0.85	287.8
0.197	0.25	20.0	8.5	14.4	3197.1	0.20	0.17	76.0
						0.30	0.26	180.6
						0.40	0.36	287.8

* See Glossary of Terms, Table 3.

TABLE 8: SUMMARY OF RUNS FOR TOTAL AMMONIA MIXING ZONE ANALYSIS IN THE AVON RIVER
CONDITION: SUMMER/FALL, DRY WEATHER, WPCP 3-YR. AVERAGE CONCENTRATION*

						CS = 0.02 mg/L		
QEFL (m^3/sec)	QPUP (m^3/sec)	TEMP (°C)	PH	CEFL (mg/L)	XSCE (m)	QY/QT	CEA (mg/L)	XSCEA (m)
0.197	0.25	10.0	7.7	2.6	121.0	0.20	1.97	80.5
						0.30	2.94	201.6
						0.40	3.92	328.0
0.197	0.25	10.0	8.1	2.6	1024.0	0.20	0.80	80.8
						0.30	1.19	201.6
						0.40	1.58	328.0
0.197	0.25	10.0	8.5	2.6	2955.2	0.20	0.33	83.2
						0.30	0.49	201.6
						0.40	0.65	328.0
0.197	0.25	15.0	7.7	2.6	286.3	0.20	1.36	79.4
						0.30	2.04	186.7
						0.40	2.73	308.6
0.197	0.25	15.0	8.1	2.6	1209.7	0.20	0.55	81.0
						0.30	0.83	186.7
						0.40	1.11	308.6
0.197	0.25	15.0	8.5	2.6	2322.5	0.20	0.23	78.1
						0.30	0.35	186.7
						0.40	0.46	308.6
0.197	0.25	20.0	7.7	2.6	290.5	0.20	0.95	77.5
						0.30	1.44	179.5
						0.40	1.96	283.0
0.197	0.25	20.0	8.1	2.6	1146.5	0.20	0.39	75.6
						0.30	0.59	179.5
						0.40	0.80	283.0
0.197	0.25	20.0	8.5	2.6	1679.2	0.20	0.17	75.9
						0.30	0.25	179.5
						0.40	0.34	283.0
0.197	0.25	25.0	7.7	2.6	351.0	0.20	0.68	74.9
						0.30	1.05	131.4
						0.40	1.46	224.5
0.197	0.25	25.0	8.1	2.6	912.2	0.20	0.28	72.4
						0.30	0.43	131.4
						0.40	0.60	244.5
0.197	0.25	25.0	8.5	2.6	1435.6	0.20	0.12	72.7
						0.30	0.19	131.4
						0.40	0.26	244.5

* See Glossary of Terms, Table 3.

TABLE 9: SUMMARY OF RUNS FOR TOTAL AMMONIA MIXING ZONE ANALYSIS IN THE AVON RIVER
CONDITION: SUMMER/FALL, DRY WEATHER, MAXIMUM OBSERVED CONCENTRATION*

QEFL (m^3/sec)	QPUP (m^3/sec)	TEMP (°C)	PH	CEFL (mg/L)	XSCE (m)	CS = 0.02 mg/L QY/QT	CEA (mg/L)	XSCEA (m)
0.197	0.25	10.0	7.7	12.6	2246.3	0.20	2.03	82.5
						0.30	3.07	202.9
						0.40	4.14	333.5
0.197	0.25	10.0	8.1	12.6	4492.1	0.20	0.82	83.3
						0.30	1.24	202.9
						0.40	1.67	333.5
0.197	0.25	10.0	8.5	12.6	6770.2	0.20	0.34	79.6
						0.30	0.51	202.9
						0.40	0.69	333.5
0.197	0.25	15.0	7.7	12.6	1924.4	0.20	1.40	81.4
						0.30	2.12	187.7
						0.40	2.89	313.7
0.197	0.25	15.0	8.1	12.6	3320.2	0.20	0.57	78.0
						0.30	0.86	187.8
						0.40	1.17	313.7
0.197	0.25	15.0	8.5	12.6	4630.9	0.20	0.24	78.2
						0.30	0.36	187.8
						0.40	0.49	313.7
0.197	0.25	20.0	7.7	12.6	1492.2	0.20	0.98	75.7
						0.30	1.50	180.5
						0.40	2.07	287.6
0.197	0.25	20.0	8.1	12.6	2331.4	0.20	0.40	75.9
						0.30	0.62	180.5
						0.40	0.85	287.6
0.197	0.25	20.0	8.5	12.6	3083.5	0.20	0.17	76.0
						0.30	0.26	180.5
						0.40	0.36	287.6
0.197	0.25	25.0	7.7	12.6	1308.9	0.20	0.70	72.6
						0.30	1.09	132.2
						0.40	1.54	248.9
0.197	0.25	25.0	8.1	12.6	1557.7	0.20	0.29	72.8
						0.30	0.45	132.2
						0.40	0.64	248.9
0.197	0.25	25.0	8.5	12.6	2025.2	0.20	0.13	72.9
						0.30	0.20	132.2
						0.40	0.28	248.9

* See Glossary of Terms, Table 3.

TABLE 10: SUMMARY OF RUNS FOR TOTAL AMMONIA MIXING ZONE ANALYSIS IN THE AVON RIVER
CONDITION: WET WEATHER, BASE CASE CONDITIONS*

DATE	QEFL (m^3/sec)	QPUP (m^3/sec)	TEMP (°C)	PH	CEFL (mg/L)	XSCE (m)	CS = 0.02 mg/L QY/QT	CEA (mg/L)	XSCEA (m)
May 5/80	0.889	6.78	17.0	8.0	8.8	4022.8	0.20	2.31	121.0
							0.30	3.47	317.7
							0.40	4.67	320.0
July 28/80	1.472	4.07	21.0	7.7	10.2	5051.6	0.20	1.49	117.6
							0.30	2.25	290.5
							0.40	3.06	320.0
Aug. 11/80	1.973	4.99	22.0	7.7	10.8	6470.7	0.20	1.30	121.0
							0.30	1.97	304.6
							0.40	2.67	320.0
Sept.17/80	0.531	2.61	15.0	7.9	6.18	778.0	0.20	2.30	110.2
							0.30	3.46	273.9
							0.40	4.64	283.2
Sept.22/80	2.748	7.26	17.0	7.7	11.18	9828.9	0.20	1.92	121.0
							0.30	2.89	328.3
							0.40	3.88	336.0

* See Glossary of Terms, Table 3.

TABLE 11: SUMMARY OF RUNS FOR TOTAL AMMONIA MIXING ZONE ANALYSIS IN THE AVON RIVER
CONDITION: WET WEATHER, STORAGE/TREATMENT CONDITIONS*

DATE	QEFL (m^3/sec)	QPUP (m^3/sec)	TEMP (^oC)	PH	CEFL (mg/L)	XSCE (m)	CS = 0.02 mg/L QY/QT	CEA (mg/L)	XSCEA (m)
May 5/80	0.827	6.72	17.0	8.0	8.6	3226.8	0.20	2.44	121.0
							0.30	3.67	317.5
							0.40	4.93	320.0
July 28/80	1.319	3.91	21.0	7.7	10.0	4486.9	0.20	1.57	117.2
							0.30	2.37	288.0
							0.40	3.20	295.1
Aug.11/80	1.940	4.95	22.0	7.7	10.8	6385.8	0.20	1.31	121.0
							0.30	1.98	304.2
							0.40	2.69	320.0
Sept.17/80	0.324	2.42	15.0	8.0	2.5	97.7	0.20	2.60	103.8
							0.30	3.90	267.8
							0.40	5.21	266.3
Sept.22/80	2.396	6.91	17.0	7.7	11.06	8452.9	0.20	2.05	121.0
							0.30	3.08	325.2
							0.40	4.14	320.0

* See Glossary of Terms, Table 3.

Results of the field work with rhodamine-Wt dye are summarized in Figure 2. It can be seen that the dye plume occupied slightly more than half the river width at Transect B, about 90% of the width at Transect C and the entire width at Transect D. Although the dye plume had crossed the river at Transect D, the concentration was not uniform at this point.

The analysis of chlorine revealed a marked sensitivity of chlorine decay to temperature; this is highlighted in Figure 3 for dry weather conditions. Under the existing treatment system, the mixing zone length varies from 70 m to 517 m depending on factors such as temperature, streamflow, etc. Existing disinfection system provides full chlorination under normal operation and partial chlorination when bypass occurs. Imposing a 40% limited use zone requirement, and thereby allowing a 60% zone of passage for fish, the allowable effluent concentration under adverse conditions could be as low as 13 ug/L (Table 4, September 22 storm event). Less adverse conditions would permit concentrations up to 80 ug/L (Table 3). In either case, these concentrations are well below existing concentrations and would call for dechlorination or an alternative disinfection technique if they were enforced. The same obviously holds true for a more stringent criterion based on a narrower limited use zone such as 20%.

The outcome of NH_3 analysis is more complex since more variables are considered; in particular pH becomes an important parameter, NH_3 effluent concentrations are varied over the observed range, and alternative instream unionized NH_3 target levels are considered. Dry weather NH_3 mixing zone results are summarized in Figures 4, 5 and 6. Th relationship between effluent concentration and the mixing zone length under typical dry weather summer conditions is shown in Figure 6. Cross referencing information here with the frequency distribution data for summer NH_3 effluent concentrations in Figure 5, one sees that 32% of the time, the mixing zone length for the PWQO is less than 300 m while 50% of the time it could exceed 900 m. Under very adverse conditions - high pH, low temperature and high effluent concentration (Table 9, 3rd test) - the mixing zone length is 6770 m for the PWQO. For the wet weather bypass events that are modelled, the mixing zone lengths under existing treatment conditions range from 778 to 9829 m. With additional storage and treatment capacity, these values drop to 98 to 8453 m respectively.

Allowable effluent concentrations of total ammonia for dry weather conditions are depicted in Figure 4. Values shown here provide for a limited use zone of 40%. The influence of pH and temperature are illustrated here. Using average summer conditions (20^{o}C, pH = 8.1) as a design case, the existing mean concentration (2.6 mg/L) is over three times the level, 0.8 mg/L, required to meet the PWQO. Effluent concentrations do, however, fall within the required range, below 1 mg/L, about 30% of the time during the summer and fall (Figure 5). During the spring, effluent concentrations tend to be higher, but lower water temperatures result in higher allowable concentrations.

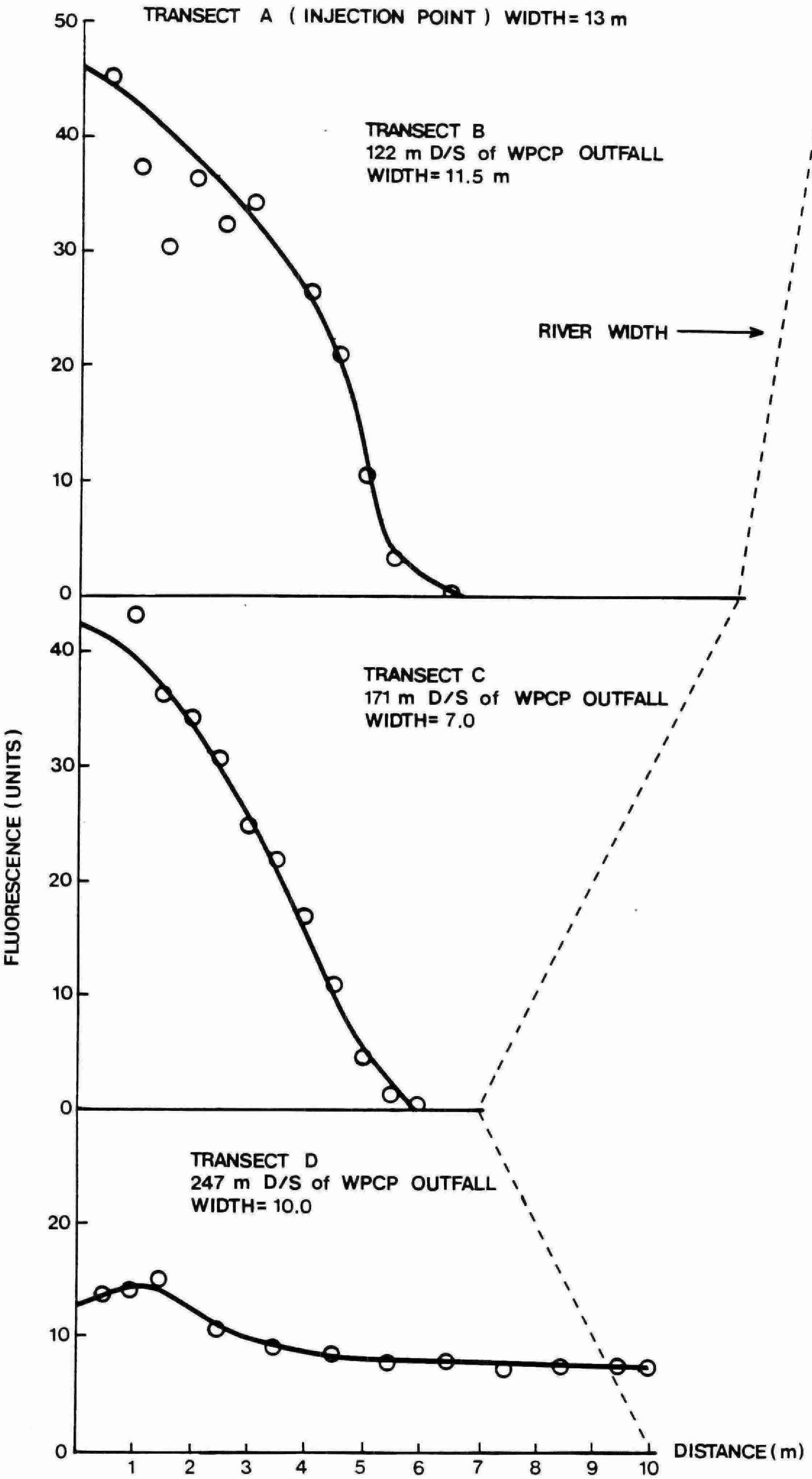


FIGURE 2: TRANSVERSE DISTRIBUTIONS OF RHODAMINE WT DYE IN MIXING ZONE TRANSECTS BELOW STRATFORD WPCP OUTFALL

FIGURE 3: PLOT SHOWING THE RELATIONSHIP BETWEEN TEMPERATURE AND MIXING ZONE LENGTH FOR TRC

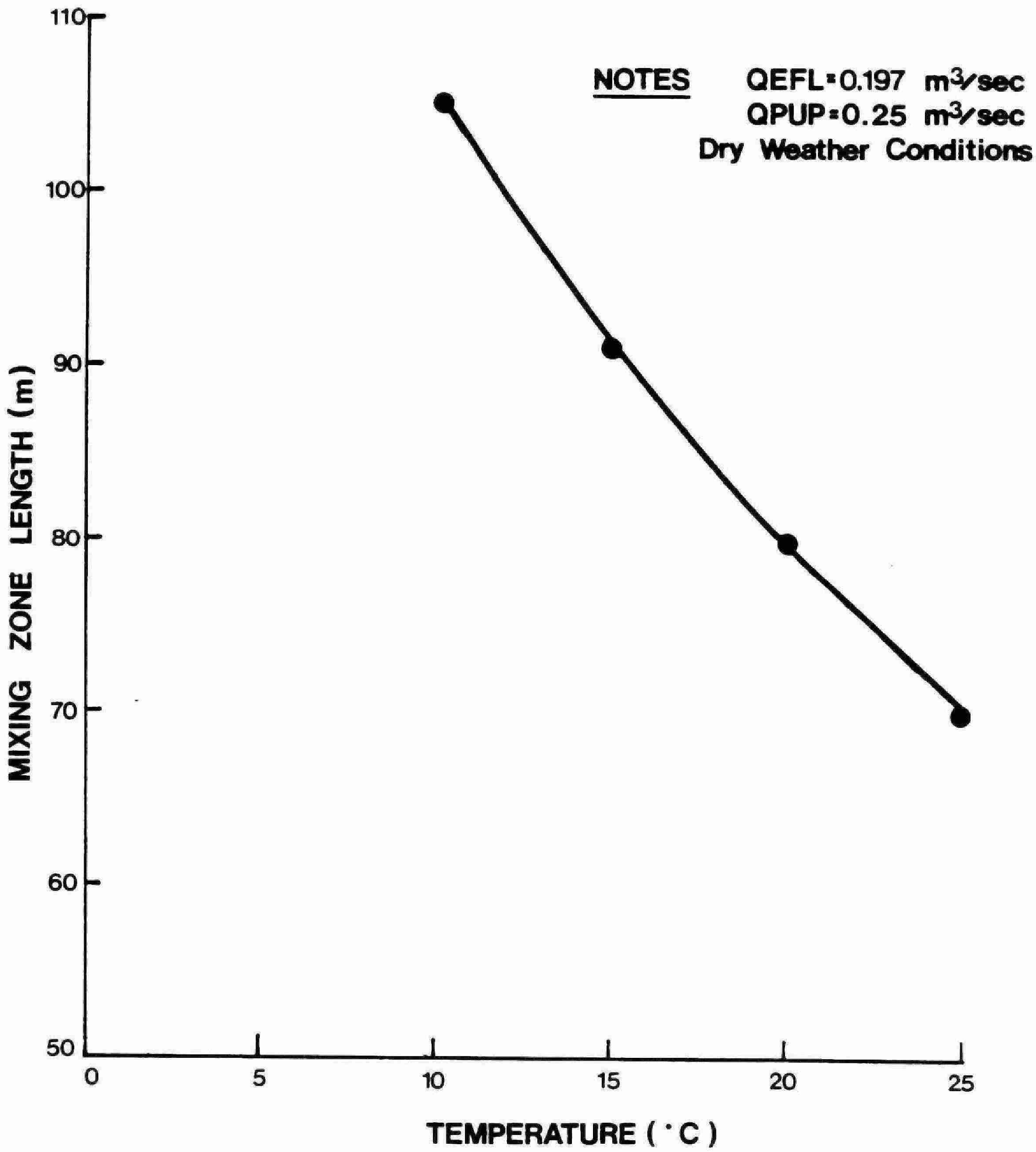


FIGURE 5: HISTOGRAM OF OBSERVED FREQUENCY DISTRIBUTION OF NH_3 CONCENTRATION IN STRATFORD WPCP EFFLUENT FOR DRY WEATHER CONDITIONS

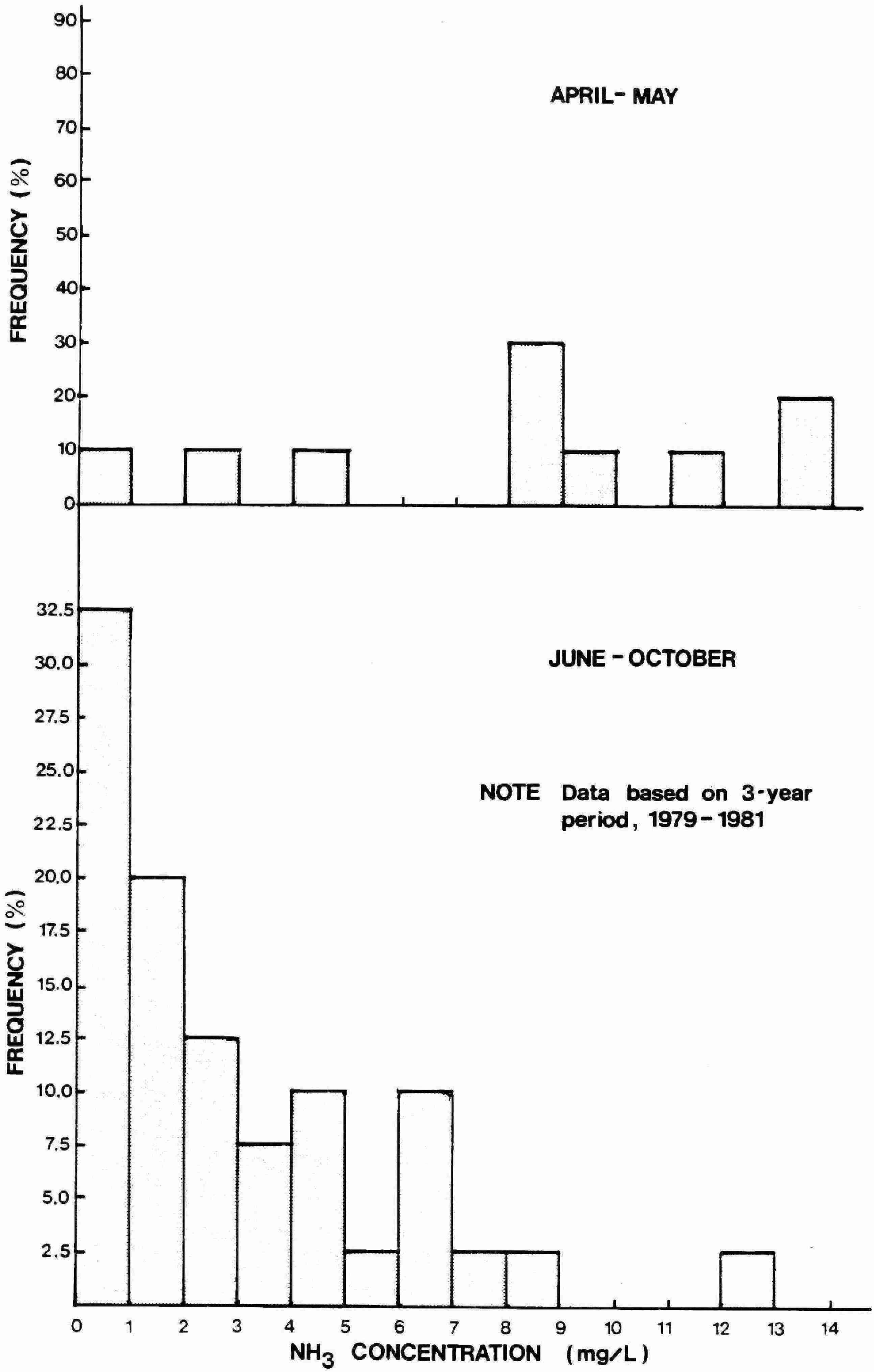
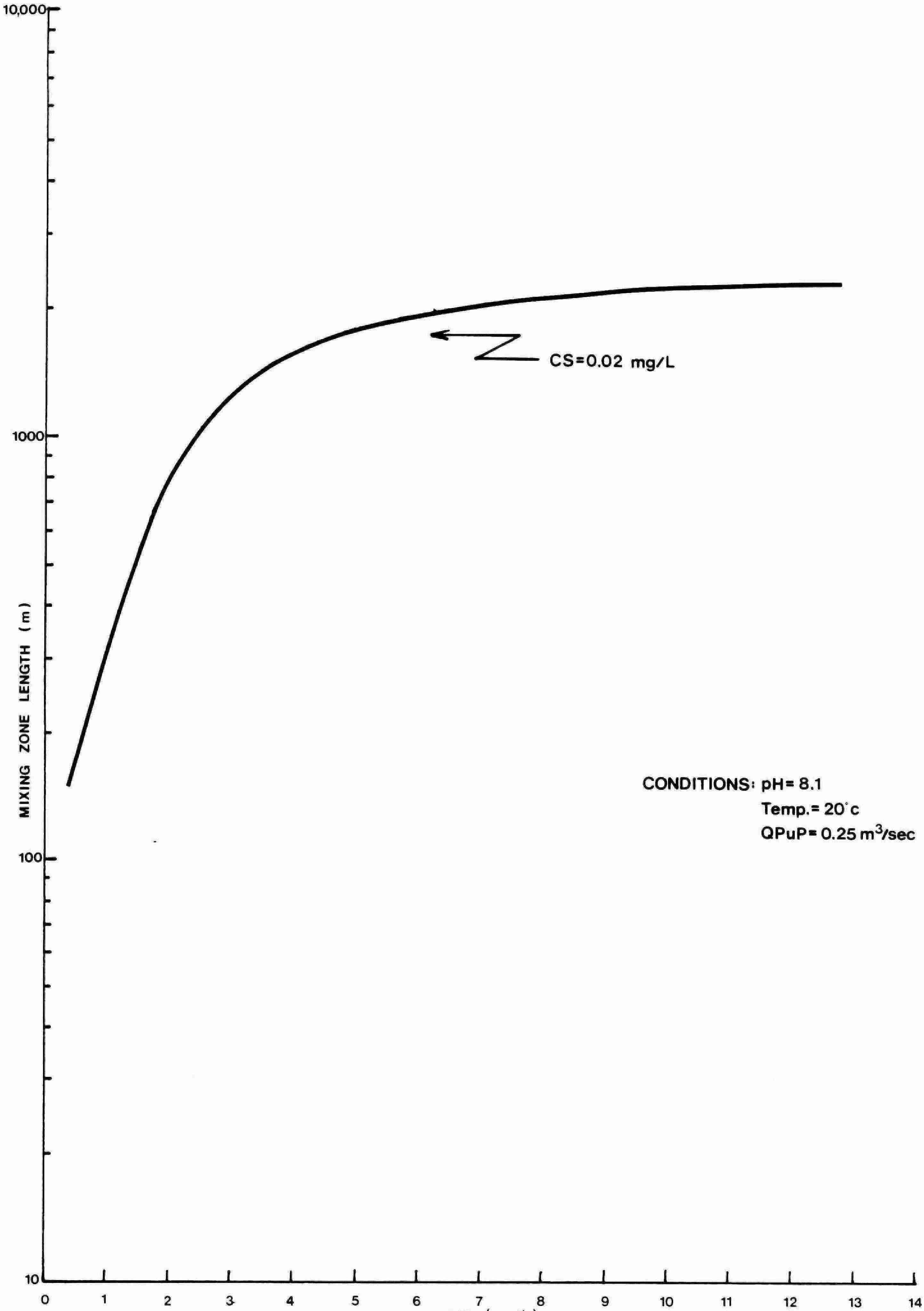


FIGURE 6: PLOT OF MIXING ZONE LENGTH VERSUS NH_3 CONCENTRATION



During wet weather bypass events, allowable concentrations associated with a 40% limited use zone vary between 2.7 and 4.7 mg/L. Effluent concentrations under the existing treatment system and with added storage and treatment capacity violate this range. The exception to this occurs when all bypass is eliminated (Table 11, September 17 test) in which case ammonia levels fall to within the range called for by the PWQO. The storage/treatment option modelled here would eliminate all bypass for 4 of 13 events modelled for 1980 (personal communication, W. Wong).

Effluent requirements for NH_3 are considerably more stringent for a 20% limited use zone. For the typical summer conditions cited above (20^{o}C, pH = 8.1), the allowable concentration falls from 0.8 mg/L to 0.39 mg/L. For bypass conditions, allowable concentrations are also reduced by approximately 50%. In the case where bypassing is eliminated by the storage/treatment option, the effluent concentration is still within the allowable level.

DISCUSSION AND CONCLUSION

Under average summer flow conditions of 0.4 m^3/sec below the WPCP outfall, the mixing zone observed for TRC and total ammonia extended beyond 247 m downstream of the WPCP outfall. Because the effluent is observed to cross the entire stream width at this point, it will probably be difficult to achieve a shore attached plume for the protection of migrating aquatic fauna without realignment of the outfall position and channelization of the river bed downstream of the outfall.

In order to achieve a limited use zone covering only 40% of the river width, and therefore allowing a 60% zone of passage for aquatic life, the following concentrations of contaminants in the WPCP effluent would be required to meet the PWQO. Under the most favourable conditions, TRC concentrations could not exceed 80 ug/L based on the assumed rapid decay rate. To achieve a 20% limited use zone, less than 10 ug/L TRC would be allowable in the WPCP effluent.

Under favourable conditions, total ammonia concentrations in the effluent would have to be restricted to 4.0 mg/L to achieve a 40% limited use zone; under more typical summer conditions, concentrations would have to be less than 1.0 mg/L to achieve the same size zone. For a 20% limited use zone, total ammonia effluent requirements would have to be reduced further by approximately 50%.

The average summer effluent quality of the Stratford WPCP is currently 500 ug/L TRC and 2.6 mg/L total ammonia. Because of this, it seems likely that dechlorination of effluent or an alternative disinfection technology would be needed to meet the PWQO for chlorine. Additional treatment of effluent for nitrification would also be needed to achieve a satisfactory mixing zone for ammonia more than 30% of the time. Compliance under storm event loadings to the WPCP essentially means the elimination of all bypass.

STRATFORD-AVON RIVER ENVIRONMENTAL MANAGEMENT PROJECT
LIST OF TECHNICAL REPORTS

S-1 Impact of Stratford City Impoundments on Water Quality in the Avon River
S-2 Physical Characteristics of the Avon River
S-3 Water Quality Monitoring of the Avon River - 1980, 1981
S-4 Experimental Efforts to Inject Pure Oxygen into the Avon River
S-5 Experimental Efforts to Aerate the Avon River with Small Instream Dams
S-6 Growth of Aquatic Plants in the Avon River
S-7 Alternative Methods of Reducing Aquatic Plant Growth in the Avon River
S-8 Dispersion of the Stratford Sewage Treatment Plant Effluent into the Avon River
S-9 Avon River Instream Water Quality Modelling
S-10 Fisheries of the Avon River
S-11 Comparison of Avon River Water Quality During Wet and Dry Weather Conditions
S-12 Phosphorus Bioavailability of the Avon River
S-13 A Feasibility Study for Augmenting Avon River Flow by Ground Water
S-14 Experiments to Control Aquatic Plant Growth by Shading
S-15 Design of an Arboreal Shade Project to Control Aquatic Plant Growth

U-1 Urban Pollution Control Strategy for Stratford, Ontario - An Overview
U-2 Inflow/Infiltration Isolation Analysis
U-3 Characterization of Urban Dry Weather Loadings
U-4 Advanced Phosphorus Control at the Stratford WPCP
U-5 Municipal Experience in Inflow Control Through Removal of Household Roof Leaders
U-6 Analysis and Control of Wet Weather Sanitary Flows
U-7 Characterization and Control of Urban Runoff
U-8 Analysis of Disinfection Alternatives

R-1 Agricultural Impacts on the Avon River - An Overview
R-2 Earth Berms and Drop Inlet Structures
R-3 Demonstration of Improved Livestock and Manure Management Techniques in a Swine operation
R-4 Identification of Priority Management Areas in the Avon River
R-5 Occurrence and Control of Soil Erosion and Fluvial Sedimentation in Selected Basins of the Thames River Watershed
R-6 Open Drain Improvement
R-7 Grassed Waterway Demonstration Projects
R-8 The Controlled Access of Livestock to Open Water Courses
R-9 Physical Characteristics and Land Uses of the Avon River Drainage Basin
R-10 Stripcropping Demonstration Project
R-11 Water Quality Monitoring of Agricultural Diffuse Sources
R-12 Comparative Tillage Trials
R-13 Sediment Basin Demonstration Project
R-14 Evaluation of Tillage Demonstration Using Sediment Traps
R-15 Statistical Modelling of Instream Phosphorus
R-16 Gully Erosion Control Demonstration Project
R-17 Institutional Framework for the Control of Diffuse Agricultural Sources of Water Pollution
R-18 Cropping-Income Impacts of Management Measures to Control Soil Loss
R-19 An Intensive Water Quality Survey of Stream Cattle Access Sites

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